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COMMUNICATIONS CHANNELS FOR TELEMECHANICS

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[Figures referred to are appended]

Telemechanics arrangements -- telemetering, telecontrol and telesignalling -- are being introduced more and more as necessary means of improving dispatcher control of power systems, long-distance control of automatic hydroelectric power stations and substations. The conditions of using telemechanics, possibilities and time required for construction, and also the choice of the type of telemechanical arrangements are determined to a considerable extent by the availability and character of existing communications channels. The reliability and stability of operation of telemechanics installations depends on the quality of the communications channel.

Owing to considerations of economy, it is not usual to assign special wires on communications lines to telemechanics channels. As a rule existing telephone wires or high-voltage power transmission lines are used to transmit telemechanics signals simultaneously with the telephoning, with the aid of channel consolidation.

The simplest method of consolidating communications lines is a circuit with a differential transformer (Figure 1). The telephone circuit terminates at both ends with differential transformers DT, to the mid-points of which are connected the transmitting TM-1 and receiving TM-2 telemechanics devices.

When the resistances of the telephone circuit wires and the impedance of both halves of the differential transformer windings are equal, the currents I_1 and I_2 from the telemechanics devices are equal and have practically no effect on the telephone apparatus T. To protect the telephone circuit from higher harmonics formed when the telemechanics signals are transmitted, and to eliminate interference on the telephone channel, so-called telegraphic filters are fitted between the telemechanics device and the mid-points of the two transformers, as is shown on Figure 2. The current is supplied by the line battery LB connected at one end of the transmission channel.

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The main advantages of the channel formed by differential transformers are its simplicity, cheapness, and accessibility in all cases where a communications circuit already exists.

At the same time, this method has substantial drawbacks. When the resistance of one wire alters, e.g., when a line contact of the insulation deteriorates, the interference in the principal circuit becomes so great that telephone transmission is impossible. When there is a sharp drop in the wire insulation (in rain, etc) and the current leaks to ground, the operating current in the windings of the line relay falls below the permissible value and the relay either ceases to function or operates erratically. This can be prevented by increasing the voltage of the line battery, but to do so is often inconvenient or impossible.

In spite of these drawbacks, until recently the devices of the frequency-pulse telemetering system of Mosenergo operated over channels with differential transformers. The line battery voltage was 24 v, which was insufficient in many cases.

A better method is to transmit telemechanics systems with currents of carrier frequencies in the 6.0-7.0 kc range. The transmitting device is a vacuum tube oscillator with a frequency of 6,500 kc. To the telemechanics device is connected a relay whose contacts switch on the output amplifier of the transmitter. The receiver consists of a one-tube amplifier and a tube detector whose plate circuit contains the receiving relay. The method of connecting the device is shown on Figure 3. The communications circuit contains standard line filters consisting of the choke filter D which passes frequencies below 2.8 kc and the condenser filter K which passes all frequencies above 2.8 kc, connected in parallel. To the former are connected the telephones T or the switches; to the latter, the devices for transmitting telemechanics signals.

To limit the output of high harmonics from the transmitter and to increase the selectivity of the receiver, special band filters P, passing frequencies in the 6.0-7.0 kc band only, are fitted between the filter K and the transmitter (receiver). A diagram of the filter link is shown on Figure 4.

The diagrammatic circuit of the transmitter shown in Figure 5 consists of a parallel-fed master oscillator using a 6L6 tube and designed for a frequency of 6.5 kc. The output cascade uses two 6L6 tubes in a push-pull circuit and operating in Class A.

The cascade is controlled by the relay contacts which connect the negative plate voltage. The push-pull amplifier circuit and the inclusion of resistors between the plates and cathodes of the amplifying tubes reduce distortion of the carrier-frequency current curve. The transmitter power is about 4 w.

The receiver (Figure 6) consists of two stages. The first, the voltage amplifier, uses a 2K2M tube; the second, a power amplifier and, at the same time, a plate detector, uses a TO-142 tube. The biases on the tube grids are obtained from the filament circuits, which are DC-fed. The receiver sensitivity can be seen from the following table:

Level of reception, nepers	$-\infty$	-2.7	-2.0	-1.4	-1.0
Input voltage	0	0.05	0.1	0.2	0.275
Current in receiving relay, ma	0	0	0.25	2.75	4.5

Level of reception, nepers	-0.8	-0.65	-0.4	+0.05	+0.3
Input voltage	0.35	0.4	0.5	0.8	1.0
Current in receiving relay, ma	6	6.25	6.75	7.25	7.5

The device under discussion was designed by TsLEM /Central Laboratory for Electric Machines?/ of Mosenergo in 1947 and is now operating successfully on a bimetallic circuit over 200 km long with a cable insert 15 km long. There was no interference in the voice-frequency telephone channel. When the device was switched on, it was noticed that the transmitting station had a considerable effect on the high-frequency telephone channels (SMT-34) working on the same communications line, especially at the near end.

After replacing the code line relay by a polarized relay, the sensitivity of the device increased considerably which enabled the receiving level to be lowered, and it has now been reduced to -1.3 nepers. The margin of reliability is about 0.5 nepers, i.e., the receiver level can be reduced to -1.8 nepers. The radius of action of the system is determined by the line attenuation and is 300 km along nonferrous wires and 50-70 km along steel wires.

In recent years a start has been made on introducing special high-frequency stations for transmitting telemechanics signals along 110 and 220 kv power transmission lines. These stations are connected to the power transmission lines with the aid of high-voltage condensers similar to stations for high-frequency communication or high-frequency protection.

Figure 7 is a block diagram of the transmitting and receiving stations. The station for high-frequency telemechanics channels contains a high (carrier)-frequency oscillator GVCh, from 3 to 8 low (voice)-frequency oscillators GNCh for the telemechanics channels, a filter system, and a power supply unit.

The telemechanics devices (frequency-pulse telemetering, time-division telecontrol, and telesignalization), by means of the contacts of the TM transmitting relays, act on the corresponding voice-frequency oscillators, switching them on when a signal is sent and switching them off when there is no signal. The voice frequencies, controlled by the transmitting relays, are applied to the modulator M in which modulation of the high-frequency currents takes place. The process of modulation is reduced to altering the amplitude of the carrier frequency in time with alterations in the instantaneous values of the modulating voice frequencies. The carrier frequency, modulated by all the voice frequencies, passes through the amplifier U and the line circuit LK and reaches the power transmission line through the coupling condenser KC. The power transmission line contains high-frequency blocking chokes VChZ, which prevent leakage of carrier-frequency currents.

At the receiving end, having reached the station, the carrier-frequency currents are amplified and transformed in the detector D into the sum of the voice frequencies. Subdivided by means of the filters F_1 - F_8, these frequencies reach their individual receivers U/D, where they are transformed into telemechanics signals whose form and duration coincide with the signals of the transmitting end. In view of the great diversity of control station circuits and their individual components, it is not feasible to give a detailed description.

Like the high-frequency communications station, the telemechanics stations operate in the 40-300 kc band. Each station, depending on its type, contains from three to eight individual telemechanics channels working on voice frequencies, e.g., 420, 540, 660, 780 cycles and so on through 120 /sic/ cycles. A definite frequency ratio is selected to decrease interference between channels and exclude frequencies which might be in the zone of higher harmonics of channels lower in the frequency scale.

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The receiving and transmitting relays are polarized telegraphic relays with high sensitivity (1-3 ma) and low time lag (3-5 milli sec).

Depending on the carrier frequency, the installations operate stably at a distance of up to 300 km without intermediate amplifiers with a station power of 2-4 w, depending on the type.

A comparison of the above methods of obtaining telemechanics channels undoubtedly favors high-frequency channels along power transmission lines. The decisive factors should be stability, reliability, and economy.

Practice has shown that the number of technical hitches on high-frequency channels is considerably fewer than on channels working on overhead communications lines. During a comparison period, for each high-frequency channel in the Mosenergo system there were 1.2 stoppages, 0.9 of which were along one channel due to the power transmission line being shut off for repair work on the line itself.

For each communications circuit during the same period there were 1.7 breakdowns, i.e., the susceptibility of high-frequency channels is one sixth of that for communications channels. In the vast majority of cases, damage to high-frequency channels is located in the stations, whereas channels along communications lines fail due to damaged circuits (line damage).

A considerable drawback of high-frequency channels is that, at present they go out of order whenever the power transmission line is switches off, accompanied by grounding (in 75% of cases).

The merits and drawbacks of various methods of transmitting telemechanics signals may be formulated in the following manner:

Along Channels with Differential Transformers

Advantages: cheapness and simplicity of installation; availability for all cases where there is a communications line, irrespective of the material of the wires; possibilities of transmitting signals by polarized code with DC.

Disadvantages: high sensitivity to the state of the line, weather, and quality of insulation; necessity for large voltages of the line battery when the length of the circuit is considerable; distortions introduced into the transmission channel; dependence on the intactness of the communications line; possibility of transmitting telemechanics signals only with a signal frequency of up to 40-60 pulses or periods per sec, according to conditions affecting telephone transmission.

Along Carrier Channels in the Audio Band

Advantages: comparatively simple apparatus; possibility of carrying it out even under power system conditions; stability and comparatively small dependence on the state of the communications line; suitability for transmitting signals in any practical telemechanics installations.

Disadvantages: necessity for special sources to feed the plate circuits of the installation; complication of the telephone transmission channel; dependence on the intactness of the communications line.

Along High-Frequency Channels on Power Transmission Lines

Advantages: high sensitivity and reliability of transmission; small distortion of signals; large (up to eight) number of simultaneous one-way transmissions.

Disadvantages: high cost (up to 150,000 rubles for one amplifier section); possibility of failure in service if there is a breakdown in the power transmission line of the point controlled.

In comparing the reliability of transmission of telemechanics signals along power transmission lines and along the wires of communications lines, the following points must also be taken into consideration:

1. In the case of channels along power transmission lines, there are still considerable possibilities of reducing the number of breakdowns. Switching off and grounding a three-phase line behind line blocks /isolating switches?/, and also grounding the line on the repair site through portable blocks would enable high-frequency transmission to be preserved in the vast majority of cases of breakdown and disconnection of the high-voltage lines. At the same time, breakdowns are considerably more frequent on communications lines, take a considerable time to fix, and there is no possibility of preserving telemechanics transmission during the breakdown period.

2. In cases where provision is made for switching the telemechanics transmission to another circuit in the event of damage (other communications wires, a parallel power transmission line), this switching over is more effective for high-frequency channels along high-voltage communications lines. For the latter, the probability of simultaneous damage to both circuits is considerably less than for communications lines with their great dependence on severe meteorological conditions (ice crust, strong wind, etc).

The foregoing enables one to lay down certain conditions for selecting a system and method of forming channels. It is quite obvious that the decisive factor should be reliable operation of the telemechanics channel depending, of course, on concrete conditions. It can be assessed correctly only by taking into account both the significance of the actual telemechanics installation and the responsibility and role in the power system of the telecontrolled or controlled object (station, substation, transmission line). But it is incontestable that in a very large number of cases, there are no grounds for making the requirements extremely severe and thereby incurring superfluous expenditures on equipping more expensive channels.

Channels with differential transformers should be used for transmitting telemechanics signals over short distances (50-70 km) along nonferrous wires and steel circuits in the numerous cases of lesser importance. These channels can also be used if it is necessary to transmit signals of only one telemeasurement or only telecontrol, for which the method has special advantages (possibility of two-way operation without supplementary arrangements.)

For large distances (over 100 km) and in the absence of a channel along power transmission lines, it is advisable to use the installation for "compressing" the communications line in the voice-frequency carrier band. In this case it is possible to establish the two systems described on the communications line -- a channel with differential transformers for telecontrol (telesignalization), and a channel on a frequency of 6.0-7.0 kilocycles for telemeasurement.

To ensure dispatcher control of the most important units in a system which is connected in a 110 or 220 kv network, the use of high-frequency channels along power transmission lines must be considered obligatory.

Further development of high-frequency channels along transmission lines demands solution of a number of long-standing technical problems in our laboratories, among which are:

1. Completion of work (begun more than once) on designing a portable grounding choke (reactor), necessary to ensure uninterrupted operation of high-frequency links during repair and other work on power transmission lines.

2. Design of special simplified stations with a small number of channels for high-frequency communications and telemechanics to work on intermediate voltage transmission lines (20 and 35 kv).

3. Design of the corresponding apparatus for connecting to 20 and 35 kv transmission lines -- coupling condensers, etc.

/Appended figures follow./

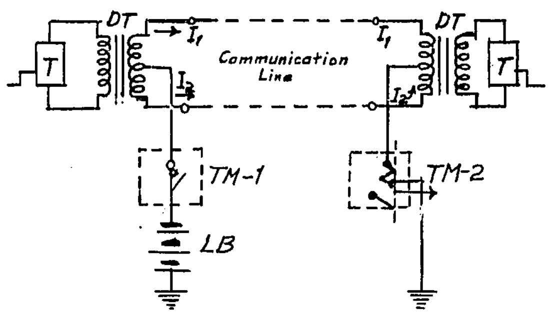

Figure 1

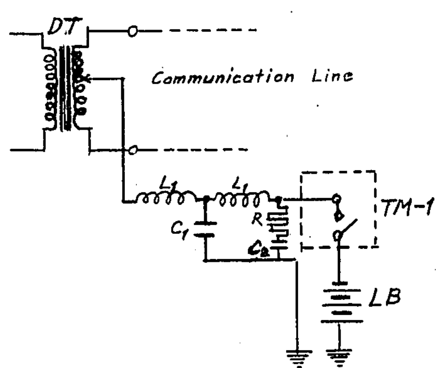

Figure 2

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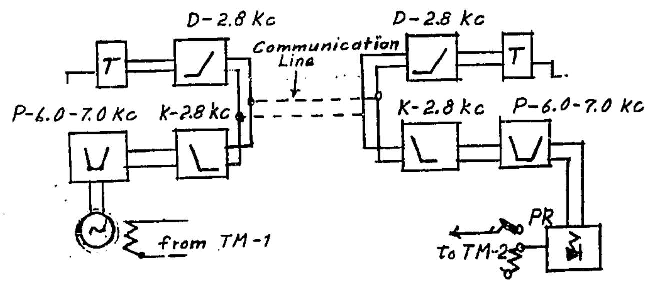

Figure 3

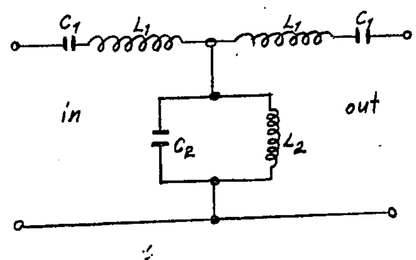

Figure 4

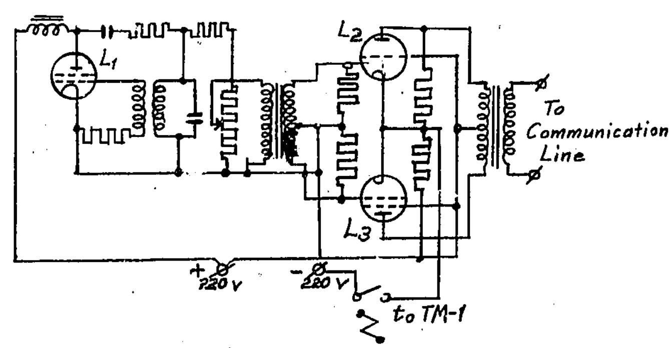

Figure 5

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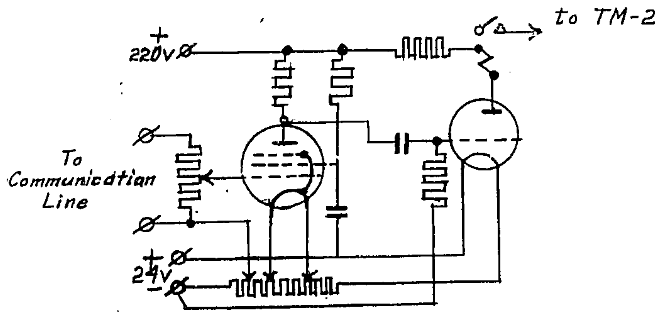

Figure 6

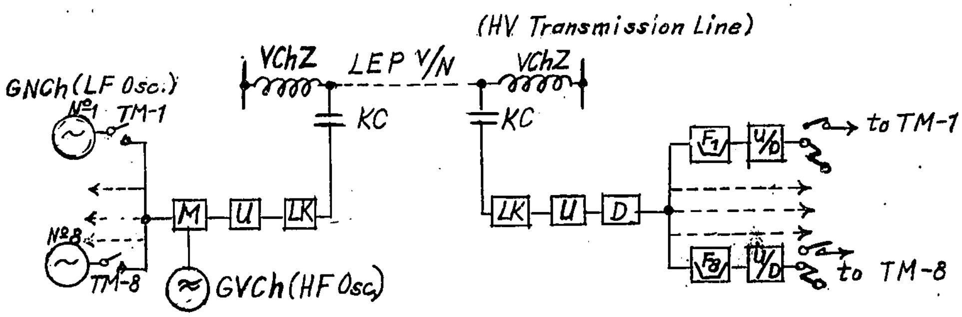

Figure 7

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